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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

REPORT No. 279

TESTS ON MODELS OF THREE BRITISH AIRPLANES IN THE VARIABLE DENSITY WIND TUNNEL

By GEORGE J. HIGGINS, W. S. DIEHL, and GEORGE L. DeFOE

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AERONAUTICAL SYMBOLS

1. FUNDAMENTAL AND DERIVED UNITS

	Symbol	Metric		English	
		Unit	Symbol	Unit	Symbol
Length	l	meter	m	foot (or mile)	ft. (or mi.)
Time	t	second	sec	second (or hour)	sec. (or hr.)
Force	F	weight of one kilogram	kg	weight of one pound	lb.
Power	P	kg/m/sec		horsepower	HP.
Speed		km/hr		mi./hr	M. P. H.
		m/sec		ft./sec	f. p. s.

2. GENERAL SYMBOLS, ETC.

W, Weight, $=mg$

g, Standard acceleration of gravity $=9.80665$ m/sec.$^2=32.1740$ ft./sec.^{2}

m, Mass, $=\frac{W}{g}$

ρ, Density (mass per unit volume).

Standard density of dry air, 0.12497 (kg-m^{-4} sec.^{2}) at 15° C and 760 mm $=0.002378$ (lb.-ft.$^{-4}$ sec.^{2}).

Specific weight of "standard" air, 1.2255 kg/m$^3=0.07651$ lb./ft.^{3}

mk^2, Moment of inertia (indicate axis of the radius of gyration, k, by proper subscript).

S, Area.

S_w, Wing area, etc.

G, Gap.

b, Span.

c, Chord length.

b/c, Aspect ratio.

f, Distance from $c.\ g.$ to elevator hinge.

μ, Coefficient of viscosity.

3. AERODYNAMICAL SYMBOLS

V, True air speed.

q, Dynamic (or impact) pressure $=\frac{1}{2}\rho V^2$

L, Lift, absolute coefficient $C_L=\frac{L}{qS}$

D, Drag, absolute coefficient $C_D=\frac{D}{qS}$

C, Cross-wind force, absolute coefficient $C_C=\frac{C}{qS}$

R, Resultant force. (Note that these coefficients are twice as large as the old coefficients L_C, D_C.)

i_w Angle of setting of wings (relative to thrust line).

i_t, Angle of stabilizer setting with reference to thrust line.

γ, Dihedral angle.

$\rho\frac{Vl}{\mu}$, Reynolds Number, where l is a linear dimension.

e. g., for a model airfoil 3 in. chord, 100 mi./hr. normal pressure, 0° C: 255,000 and at 15° C., 230,000;

or for a model of 10 cm chord 40 m/sec, corresponding numbers are 299,000 and 270,000.

C_p, Center of pressure coefficient (ratio of distance of $C.\ P.$ from leading edge to chord length).

β, Angle of stabilizer setting with reference to lower wing, $=(i_t-i_w)$.

α, Angle of attack.

ϵ, Angle of downwash.

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

This report contains the results of tests made in the National Advisory Committee for Aeronautics variable density wind tunnel on three airplane models supplied by the British Aeronautical Research Committee. These models, the BE-2E with R. A. F. 19 wings, the Bristol Fighter with R. A. F. 15 wings, and the Bristol Fighter with R. A. F. 30 wings, were tested over a wide range in Reynolds Numbers in order to supply data desired by the Aeronautical Research Committee for scale effect studies.

The maximum lifts obtained in these tests are in excellent agreement with the published results of British tests, both model and full scale. No attempt is made to compare drag data, owing to the

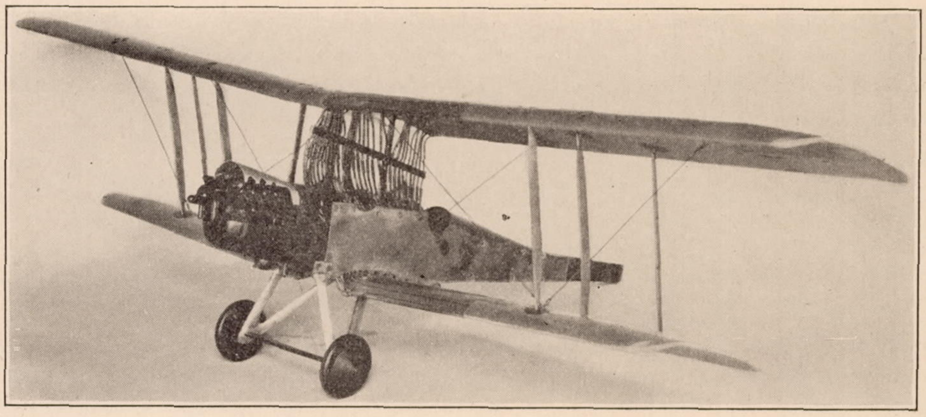

FIG. 1.—BE-2E airplane model with special equipment as tested

omission of tail surfaces, radiator, etc., from the model, but it is shown that the scale effect observed on the drag coefficients in these tests is due to a large extent to the parts of the models other than the wings.

INTRODUCTION

At the request of the British Aeronautical Research Committee, nominal models of three British airplanes incorporating wing sections of widely different aerodynamic characteristics, have been tested in the variable density wind tunnel over a range in Reynolds Number extending from about 150,000 to more than 3,000,000. These models have been designated as "nominal," since no attempt was made to incorporate all details necessary for geometrical similarity; the omission of the tail surfaces and radiators being the most important deviations in this respect. The tests on such models may be expected to indicate the scale effect on lift with fair accuracy, but previous experience with the variable density wind tunnel has shown that the drag data are not reliable unless exact geometric similarity is obtained. (See reference 1.) The foregoing limitations must be borne in mind in any interpretation of the test results.

The purpose of these tests was to supply data for comparative studies by the British Aeronautical Research Committee. The models had previously been tested very thoroughly in England, and comparisons made with full scale flight test data on the airplanes represented.

DESCRIPTION OF MODELS AND METHOD OF TESTING

The three models, consisting of a BE–2E to one-twelfth scale fitted with R. A. F. 19 wings, and two Bristol Fighters to one-fifteenth scale fitted with R. A. F. 15 and R. A. F. 30 wings, were tested as supplied by the British Aeronautical Research Committee. The constructional details of the models are clearly shown in Figures 1 to 5. It will be noted that the tail surfaces are omitted and that various other details do not conform to the requirements of geometrical similarity. For this reason it is desired to emphasize the fact that the test data are valid only in comparison with data obtained in other tests on the same or similar models.

The method of mounting the models during the tests is shown in Figures 2, 3, and 5. The model is supported by two vertical stream-line rods which are hinged at their point of attachment to the model and rigidly connected to the balance at their lower ends. A short horizontal yoke rigidly attached to the shielded vertical balance bar, extends upstream and is hinged to the rear of the model. The angle of attack is changed at the operating panel outside of the tunnel, through an electric drive which raises or lowers the vertical balance bar. A detailed explanation of the operation of the balance in measuring lift, drag, and pitching moments is given in reference 2. The interference between the shielded vertical balance bar and the model was carefully investigated in the tests on the Sperry Messenger model (reference 1) and found to be negligible.

TEST RESULTS

Each model was tested at pressures of approximately 1, 2½, 5, 10, and 20 atmospheres. In each test the dynamic pressure was held as nearly constant as practicable at a value corresponding to a velocity of about 22 meters per second. The coefficients are based on the true dynamic pressure which was determined for each observation. Drag coefficients and angles of attack have been corrected for tunnel wall effect by the Prandtl formulas,

$$\Delta C_D=\frac{C_L^2 S}{2\pi D^2},$$

and

$$\Delta\alpha=\frac{57.3\ C_L S}{2\pi\ D^2}$$

where S is the model wing area, and D the tunnel diameter. In tabulating the test data, both corrected and uncorrected values of C_D and α have been given. The test data are given in Tables I to XV inclusive and the various plots of these data in Figures 6 to 26 inclusive.

The usual absolute coefficients have been used. These are defined by the relations:

$$\text{Lift} = C_L\, q\, S$$

$$\text{Drag} = C_D\, q\, S$$

$$\text{Pitching moment about reference axis} = C_M\, q\, Sc$$

where q is the dynamic pressure $\frac{1}{2}\rho V^2$ and S the wing area.

The center of gravity locations for the three models were not given, so arbitrary reference axes have been taken. The location of these axes is given along with the model dimensions in Table XVI.

The following summary of tables and figures is included for convenience:

BE–2E with R. A. F. 19 wings:

- Test data at 1, 2½, 5, 10, and 20 atmospheres—Tables I to V inclusive.
- C_L vs. α—Figure 6.
- C_D vs. α—Figure 7.
- C_D vs. C_L—Figure 8.
- L/D vs. C_L—Figure 9.
- C_M vs. C_L—Figure 10.

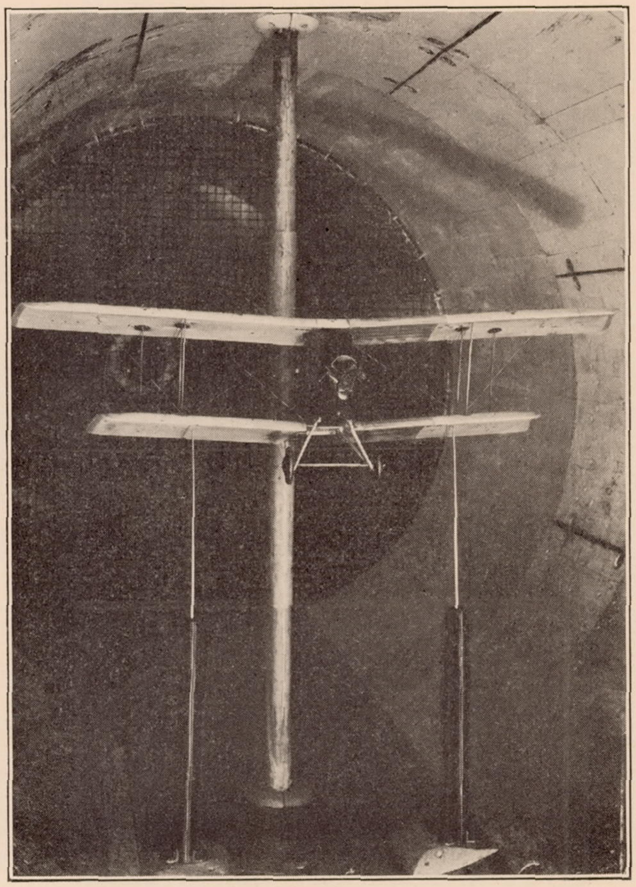

FIG. 2.—BE-2E airplane model mounted in tunnel

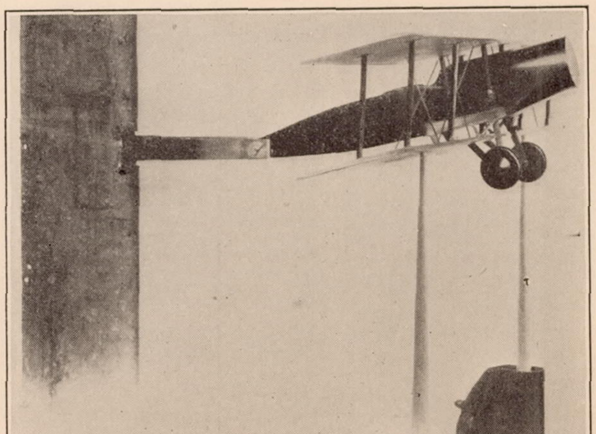

FIG. 3.—Bristol Fighter airplane model with R. A. F. 15 wings as mounted in tunnel

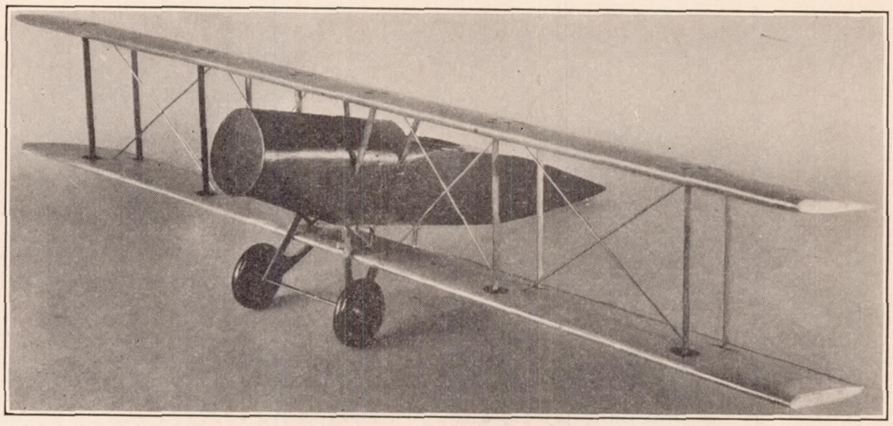

FIG. 4.—Bristol Fighter airplane model with R. A. F. 30 wings

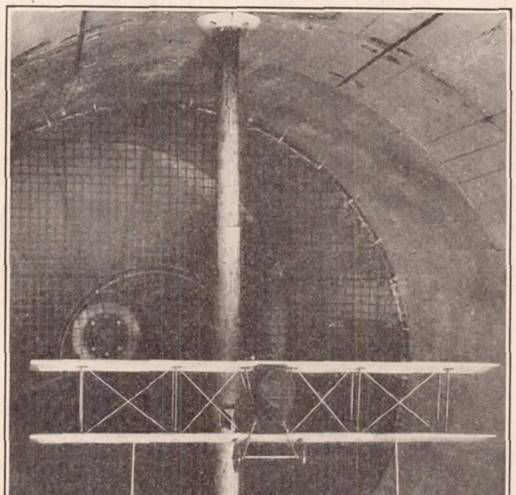

FIG. 5.—Bristol Fighter airplane model with R. A. F. 30 wings mounted in tunnel

BE–2E with R. A. F. 19 wings—Continued.

$C_{L_{max.}}$ and α vs. Reynolds Number—Figure 11.
$C_{L_{max.}}$ vs. Reynolds Number—Figure 12.
$C_{D_{max.}}$ vs. Reynolds Number—Figure 13.
Dimensional data on model—Table XVI.

Bristol Fighter with R. A. F. 15 wings:

Test data at 1, 2½, 5, 10, and 20 atmospheres—Tables VI to X inclusive.
C_L vs. α—Figure 14.
C_D vs. α—Figure 15.
C_D vs. C_L—Figure 16.
L/D vs. C_L—Figure 17.
C_M vs. C_L—Figure 18.
$C_{L_{max.}}$ vs. Reynolds Number—Figure 19.
$C_{D_{min.}}$ vs. Reynolds Number—Figure 20.
Dimensional data on model—Table XVI.

Bristol Fighter with R. A. F. 30 wings:

Test data at 1, 2½, 5, 10, and 20 atmospheres—Tables XI to XV inclusive.
C_L vs. α—Figure 21.
C_D vs. α—Figure 22.
C_D vs. C_L—Figure 23.
L/D vs. C_L—Figure 24.
C_M vs. C_L—Figure 25.
$C_{L_{max.}}$ vs. Reynolds Number—Figure 26.
$C_{D_{min.}}$ vs. Reynolds Number—Figure 20.
Dimensional data on model—Table XVI.
Comparison of sections R. A. F. 30, Göttingen 459, N. A. C. A. 99—Figure 27.

DISCUSSION OF DATA

BE–2E model with R. A. F., 19 wings:

The variation in $C_{L_{max.}}$ with Reynolds Number for this model is so great that it constitutes the most striking feature of the tests. The following tabulation of data selected from Tables I to V and Figures 6, 11, and 12, will assist in the study of the changes:

Tunnel pressure atmospheres	1	2½	5	10	20
Reynolds Number $\times 10^{-5}$	1. 915	4. 61	9. 49	18. 70	40. 0
$C_{L_{max.}}$	1. 69	1. 67	1. 62	1. 43	1. 41
Angle of attack at $C_{L_{max.}}$ α_m	21. 0°	20. 1°	19. 3°	13. 5°	12. 4°
Angle of attack for C_L=O α_o	−9. 0°	−9. 0°	−9. 0°	−8. 9°	−9. 1°
$\alpha_m - \alpha_o$	30. 0°	29. 1°	28. 3°	22. 4°	21. 5°

$C_{L_{max.}}$ is greatest at 1 atmosphere and decreases gradually up to a tank pressure of 5 atmospheres. Between 5 and 10 atmospheres, or as shown by Figure 11, between Reynolds Numbers 1,000,000 and 1,800,000 there is rapid decrease in $C_{L_{max.}}$ Increasing the Reynolds Number above this critical value causes $C_{L_{max.}}$ to decrease slightly more but at such a slow rate that the change is negligible It has been noted in previous tests in the variable density tunnel that all very thick and very highly cambered wing sections tend to show a decrease in $C_{L_{max.}}$ if the Reynolds Number be made great enough. For example, the U. S. A., 35A section is of conventional form, similar to the Göttingen 387, but having a camber of 18.18% as compared with 15.2% for the R. A. F. 19. Tests on this section (reference 3) show that at 1 atmosphere $C_{L_{max.}}=1.57$ and at 20 atmospheres $C_{L_{max.}}=1.21$, with intermediate values closely parallel to those found for the R. A. F. 19. It therefore follows that very high lifts on highly cambered sections found in tests at moderate Reynolds Numbers should be viewed with suspicion since it is unlikely that they can be realized at full scale.

That these characteristics are inherent with the R. A. F. 19 section, and are not an interference effect, is clearly evident from the comparison in Figure 12 of the curves of $C_{L_{max.}}$ against Reynolds Number for R. A. F. 19 section alone and for the BE–2E model. It is of interest to note in this connection that data on the R. A. F. 19 section have been obtained at very low Reynolds Numbers by operating the tunnel at subatmospheric pressures.

The effect of Reynolds Number on C_D is not as great as on C_L, but it is considerable, as shown by the following tabulation of $C_{D_{min.}}$ from the data in Tables I to V and plotted in Figure 13:

Reynolds Number $\times 10^{-5}$	1.915	4.61	9.49	18.70	40.00
$C_{D_{min.}}$	.0861	.0850	.0854	.0782	.0719

The most important feature seems to be the pronounced reduction in $C_{D_{min.}}$ concurrent with the reduction in $C_{L_{max.}}$ previously noted. By comparison with a similar curve obtained by testing the R. A. F. 19 airfoil section, it may be concluded that this scale effect is primarily due to the wings. There also seems to be a large scale effect in the second regime but inspection of the curves in Figure 7 shows that the curves may be too irregular to justify any definite conclusions. The irregularities in the curves for both C_L and C_D at low angles are probably due to the unstable nature of the flow over the lower surface near the leading edge.

The plot of C_D vs. C_L (fig. 8), brings out the scale effect on drag much better than plot of C_D vs. α. For values of C_D corresponding to values of C_L less than 1.0, there is a large scale effect on C_D, particularly noticeable for the higher Reynolds Numbers. This condition is also shown by the plotting of L/D vs. C_L, Figure 9.

The moment curves of Figure 10 are rather irregular and do not indicate any very definite tendency except that at the higher lift coefficients the 10 and 20 atmosphere curves are displaced very slightly towards the base line.

Bristol Fighter with R. A. F., 15 wings:

The curves of C_L vs. α for this model, Figure 14, show no unusual features except at angles of attack greater than 12° where a moderate scale effect is found. $C_{L_{max.}}$ increases from 0.99 at 1 atmosphere to 1.11 at 2.5 atmospheres and then falls off gradually to 1.032 at 20 atmospheres, Figure 19. The constancy of the angle of attack for zero lift is again noticeable. Between $C_L=O$ and $C_L=0.9$ the divergencies of the C_L curves are small and rather inconclusive but a tendency may be observed for C_L to decrease when the Reynolds Number is increased.

The curves of C_D vs. α, Figure 15, indicate a considerable decrease in C_D as Reynolds Number is increased. If the curves for 1 and for 20 atmospheres be compared the decrease in C_D is comparatively uniform except at the critical angle range between 13° and 16°. This is shown quite clearly by the polar plot, Figure 16, which also indicates that the value of $C_{D_{min.}}$ is less at 1 atmosphere than at 2½ and 5 atmospheres. This condition is probably due to the experimental errors in reading the low drags at 1 atmosphere.

The improvement in L/D, shown by the plot of L/D vs. C_L on Figure 17, is about of the same order as that observed on the BE–2E model, Figure 9. A point of similarity is to be found in that the curves in each series fall into two groups: One containing the 1, 2½, and 5 atmosphere data, the other containing the 10 and 20 atmosphere data. This would indicate a change in flow type between the 5 and 10 atmosphere conditions for both models. Another point of interest is that $L/D_{max.}$ for the various Reynolds Numbers tends to occur at the same value of C_L for the Bristol Fighter with R. A. F. 15 wings, while for the BE–2E model the value of C_L at $L/D_{max.}$ decreases as the Reynolds Number increases.

Figure 20 contains the plot against Reynolds Number of $C_{D_{min.}}$ for the Bristol Fighter model, for the R. A. F. 15 airfoil, and for the difference between the two, representing the drag of the model less wings plus interference. It is apparent that the scale effects observed on this model are due almost entirely to parts other than the wings, and in all probability the struts account for a large proportion of the total effect.

The moment curves of Figure 18 show no well defined tendencies. The cause of the irregularity in the 10-atmosphere curve is not known and no indication of a change in flow type can be found in the remaining data at 10 atmospheres.

Bristol Fighter with R. A. F., 30 wings:

The curves of C_L vs. α for this model, Figure 21, show a very large scale effect on lift coefficients at angles of attack greater than 11°, but below this angle the effects of Reynolds Number are negligible. The angle of attack for zero lift appears to be practically unaffected by changes in Reynolds Number.

The following data have been abstracted from Tables XI to XV:

Tank pressure atmosphere	1	2½	5	10	20
Reynolds Number$\times 10^{-5}$	1. 52	4. 04	7. 60	15. 00	30. 50
$C_{L_{max}}$	0. 761	0. 814	0. 916	1. 067	1. 006
Angle of attack for $C_{L_{max}}$ ----- α_m	14. 0°	14. 0°	16. 0°	20. 0°	17. 0°
Angle of attack for C_L=O ---- α_o	−0. 4°	−0. 4°	−0. 4°	−0. 1°	−0. 4°

Both $C_{L_{max.}}$ and α_m increase with tank pressure up to 10 atmospheres, or to a Reynolds Number of about 1,800,000, above which they decrease slowly as Reynolds Number is increased. This characteristic appears to be a property of the moderately thick, double-cambered sections, as shown by the comparative plots, on Figure 26, of $C_{L_{max.}}$ vs. Reynolds Number for the present model, for the N. A. C. A. 99 airfoil and the Göttingen 459 airfoil. The Göttingen 459 section differs very little from the R. A. F. 30 but the N. A. C. A. 99 is considerably thicker at points forward of the maximum ordinate. Figure 27 is a superposed plot of the three sections, for comparison.

It is of interest to note that the major scale effect on C_L for the R. A. F. 30 section is of the same type as that for the R. A. F. 15 and the R. A. F. 19, in that it consists of an expansion or contraction of the angular range between zero and maximum lift, without any marked changes in the angle of attack for zero lift or in the slope of the lift curves $\frac{dC_L}{d\alpha}$.

The scale effect on C_D for the Bristol Fighter with R. A. F. 30 wings is about the same as that observed for the R. A. F. 15 wings, and as shown by the curves of $C_{D_{min.}}$ vs. Reynolds Number, Figure 20, it is also due to the same causes, that is, to parts other than the wings. Referring to Figure 4, it is quite apparent that the considerable length of small streamline struts and of large brace wires is responsible for the greater part of the effect observed. Consequently, it is rather difficult to apply a general interpretation to the curves of C_D or L/D.

The moment curves of Figure 25 are again erratic and show no well defined tendency. The only general conclusion justified is that the change of moment from model to full scale is probably of no great importance.

CONCLUSIONS

The following conclusions may be drawn from the present tests, due consideration being given to data previously accumulated in the variable density wind tunnel:

1. The scale effects depend on the airfoil section and are, in general, similar for similar sections.

2. All airfoil sections may be roughly divided into three general classes as follows:

(*a*) The highly cambered or very thick section having a very high lift at Reynolds Numbers within the testing range of the average wind tunnel. This class, of which the R. A. F. 19 is an example, usually shows a decrease in $C_{L_{max.}}$ with increase in Reynolds Number.

(*b*) The moderately cambered, medium lift section, of which the R. A. F. 15 is an example. This class usually has a moderate, and favorable scale effect on C_L with a fairly low and favorable scale effect on C_D.

(*c*) The thin, to moderately thick, double-cambered section of low lift at normal test Reynolds Numbers. This class, of which the R. A. F. 30 is an example, usually shows a large increase in $C_{L_{max.}}$ and a moderate decrease in $C_{D_{min.}}$ with increase in Reynolds Number.

3. The scale effect on drag found in this investigation is caused to a large extent by the wing bracing used on the models.

4. The lift coefficients obtained in the variable density wind tunnel are in excellent agreement with those found in previous tests on the same models and also with the reported full-scale data.

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REFERENCES

1. Munk, Max M., and Diehl, Walter S. "The Air Forces on a Model of the Sperry Messenger Airplane without Propeller." N. A. C. A., Technical Report No. 225. 1925.
2. Munk, Max M., and Miller, Elton W. "The Variable Density Wind Tunnel of the National Advisory Committee for Aeronautics." N. A. C. A., Technical Report No. 227. 1926.
3. Higgins, George J. "The Comparison of Well Known and New Wing Sections Tested in the Variable Density Wind Tunnel." N. A. C. A., Technical Note No. 219. 1925.
4. Garner, H. M., and Bradfield, F. B. "Lift and Drag of BE–2E with R. A. F., 19 Wings. Comparison of Full Scale and Model Results." British Aeronautical Research Committee Reports and Memoranda No. 763 (Ae. 24), August, 1921.
5. Aerodynamics Staff. "Lift and Drag of the Bristol Fighter with Wings of Three Aspect Ratios." British Aeronautical Research Committee Reports and Memoranda No. 859. (Ae. 99.) April, 1923.
6. Aerodynamics Staff. "Lift and Drag of Standard Bristol Fighter with R. A. F. 4D Engine. Comparative Full Scale and Model Tests." British Aeronautical Research Committee Reports and Memoranda No. 896. (Ae. 126.) November, 1923.
7. Munk, Max M. "Preliminary Wing Model Tests in the Variable Density Wind Tunnel of the National Advisory Committee for Aeronautics." N. A. C. A., Technical Report No. 217. 1925.
8. Wieselsberger, C., Betz, A., and Prandtl, L. "Ergebnisse der Aerodynamischen Versuchsanstalt zu Göttingen." (Results obtained in the Göttingen Aerodynamic Laboratory—Report I, 1921.)
9. Bradfield, F. B., and Hartshorn, A. S. "Test of Four Thick Aerofoils, R. A. F., 30, 31, 32, and 33." British Aeronautical Research Committee. Reports and Memoranda No. 928. (Ae. 150.) September, 1924.
10. Nutt, A. E. Woodward, Harris, R. G., and Caygill, L. E. "Full Scale and Model Measurements of Lift and Drag of Bristol Fighter with R. A. F. 30 Wings." British Aeronautical Research Committee Reports and Memoranda No. 1052. August, 1926.

TABLE I

MODEL, BE–2E (R. A. F., 19 WINGS) AIRPLANE MODEL. AVERAGE TANK PRESSURE, 1 ATM. AVERAGE DYNAMIC PRESSURE, 27.4 kg/m². AVERAGE REYNOLDS NUMBER, 191,500

Degrees α	C_L	C_D	L/D	C_M	[1] Degrees α	[1] C_D'
−11. 57	−0. 079	0. 1575	−0. 50	−0. 016	−11. 50	0. 1574
−10. 03	−. 032	. 1430	−. 22	+. 071	−10. 00	. 1430
−8. 48	+. 020	. 1300	+. 15	−. 003	−8. 50	. 1300
−6. 92	. 088	. 1185	. 74	−. 005	−7. 00	. 1184
−5. 33	. 183	. 1044	1. 75	+. 012	−5. 50	. 1038
−3. 74	. 272	. 0985	2. 76	. 012	−4. 00	. 0973
−2. 13	. 396	. 0940	4. 22	. 048	−2. 50	. 0914
−. 50	. 526	. 0861	6. 10	. 063	−1. 00	. 0816
+1. 12	. 652	. 0952	6. 85	. 085	+. 50	. 0882
2. 75	. 767	. 1049	7. 30	. 099	2. 00	. 0952
4. 35	. 898	. 1188	7. 58	. 106	3. 50	. 1055
5. 95	1. 007	. 1324	7. 64	. 120	5. 00	. 1157
7. 56	1. 117	. 1488	7. 46	. 141	6. 50	. 1283
9. 14	1. 207	. 1669	7. 25	. 144	8. 00	. 1429
10. 75	1. 317	. 1926	6. 85	. 136	9. 50	. 1640
12. 32	1. 391	. 2145	6. 50	. 148	11. 00	. 1825
13. 88	1. 462	. 2359	6. 22	. 144	12. 50	. 2006
15. 46	1. 548	. 2619	5. 92	. 135	14. 00	. 2224
17. 02	1. 608	. 2926	5. 49	. 148	15. 50	. 2500
18. 52	1. 659	. 3215	5. 16	. 138	17. 00	. 2762
20. 10	1. 689	. 3552	4. 76	. 117	18. 50	. 3082
21. 60	1. 689	. 3950	4. 28	. 131	20. 00	. 3480
23. 08	1. 672	. 4372	3. 84	. 111	21. 50	. 3911
24. 56	1. 653	. 4825	3. 43	. 108	23. 00	. 4373
26. 04	1. 633	. 5224	3. 13	. 097	24. 50	. 4784

[1] Uncorrected for tunnel wall effect.

TABLE II

MODEL, BE–2E (R. A. F., 19 WINGS) AIRPLANE MODEL. AVERAGE TANK PRESSURE, 2.47 ATM. AVERAGE DYNAMIC PRESSURE, 67.6 kg/m². AVERAGE REYNOLDS NUMBER, 461,000

Degrees α	C_L	C_D	L/D	C_M	[1] Degrees α	[1] C_D'
−11. 57	−0. 069	0. 1512	−0. 46	−0. 004	−11. 50	0. 1511
−10. 20	−. 023	. 1380	−. 17	+. 006	−10. 00	. 1380
−8. 20	+. 029	. 1228	+. 24	. 009	−8. 50	. 1228
−6. 91	. 095	. 1117	. 85	. 019	−7. 00	. 1116
−5. 32	. 190	. 1011	1. 88	. 039	−5. 50	. 1005
−3. 72	. 296	. 0967	3. 06	. 051	−4. 00	. 0953
−2. 10	. 421	. 0901	4. 67	. 068	−2. 50	. 0872
−. 47	. 559	. 0850	6. 58	. 085	−1. 00	. 0798
+1. 16	. 695	. 0949	7. 30	. 095	+. 50	. 0869
2. 76	. 799	. 1036	7. 70	. 106	2. 00	. 0930
4. 39	. 942	. 1160	8. 14	. 121	3. 50	. 1014
5. 99	1. 043	. 1304	8. 00	. 131	5. 00	. 1124
7. 58	1. 148	. 1469	7. 82	. 137	6. 50	. 1252
9. 17	1. 240	. 1647	7. 52	. 139	8. 00	. 1394
10. 77	1. 339	. 1991	6. 72	. 143	9. 50	. 1596
12. 35	1. 429	. 2101	6. 80	. 130	11. 00	. 1764
13. 93	1. 514	. 2355	6. 42	. 168	12. 50	. 1977
15. 50	1. 582	. 2605	6. 06	. 156	14. 00	. 2192
17. 05	1. 633	. 2890	5. 65	. 148	15. 50	. 2450
18. 57	1. 661	. 3248	5. 10	. 118	17. 00	. 2792
20. 07	1. 664	. 3717	4. 47	. 095	18. 50	. 3260
21. 57	1. 662	. 4111	4. 05	. 085	20. 00	. 3655
23. 06	1. 645	. 4543	3. 62	. 077	21. 50	. 4096
24. 54	1. 624	. 4943	3. 29	. 060	23. 00	. 4508
26. 00	1. 591	. 5999	2. 66	. 059	24. 50	. 5581

[1] Uncorrected for tunnel wall effect.

TABLE III

MODEL, BE–2E (R. A. F., 19 WINGS) AIRPLANE MODEL. AVERAGE TANK PRESSURE, 5.1 ATM. AVERAGE DYNAMIC PRESSURE, 144.6 kg/m². AVERAGE REYNOLDS NUMBER, 949,000

Degrees α	C_L	C_D	L/D	C_M	[1] Degrees α	[1] C_D'
−11. 57	−0. 077	. 1531	−0. 50	−0. 004	−11. 50	0. 1530
−10. 03	−. 032	. 1370	−. 23	−. 002	−10. 00	. 1370
−8. 47	+. 026	. 1249	+. 21	+. 004	−8. 50	. 1249
−6. 91	. 098	. 1129	. 87	. 009	−7. 00	. 1127
−5. 31	. 197	. 1027	1. 92	. 024	−5. 50	. 1021
−3. 71	. 310	. 0946	3. 28	. 045	−4. 00	. 0930
−2. 08	. 449	. 0880	5. 11	. 059	−2. 50	. 0847
−. 45	. 580	. 0854	6. 80	. 069	−1. 00	. 0799
+1. 16	. 696	. 0920	7. 58	. 093	+. 50	. 0840
2. 77	. 812	. 1019	7. 94	. 104	2. 00	. 0910
4. 39	. 942	. 1133	8. 34	. 106	3. 50	. 0987
5. 99	1. 045	. 1292	8. 07	. 131	5. 00	. 1112
7. 58	1. 141	. 1505	7. 58	. 134	6. 50	. 1290
9. 17	1. 241	. 1675	7. 41	. 123	8. 00	. 1420
10. 77	1. 340	. 1898	7. 04	. 138	9. 50	. 1602
12. 35	1. 427	. 2128	6. 72	. 131	11. 00	. 1792
13. 92	1. 503	. 2388	6. 29	. 134	12. 50	. 2015
15. 47	1. 553	. 2685	5. 78	. 109	14. 00	. 2287
17. 01	1. 598	. 3090	5. 18	. 105	15. 50	. 2670
18. 53	1. 621	. 3546	4. 57	. 092	17. 00	. 3112
20. 03	1. 620	. 3965	4. 08	. 073	18. 50	. 3531
21. 52	1. 608	. 4376	3. 68	. 055	20. 00	. 3950
23. 00	1. 582	. 4715	3. 36	. 072	21. 50	. 4301
24. 44	1. 525	. 5008	3. 05	. 013	23. 00	. 4624
25. 89	1. 471	. 5204	2. 83	. 009	24. 50	. 4847

[1] Uncorrected for tunnel wall effect.

TABLE IV

MODEL, BE–2E (R. A. F., 19 WINGS) AIRPLANE MODEL. AVERAGE TANK PRESSURE, 10.1 ATM. AVERAGE DYNAMIC PRESSURE, 291 kg/m². AVERAGE REYNOLDS NUMBER, 1,870,000

Degrees α	C_L	C_D	L/D	C_M	[1] Degrees α	[1] C_D'
−11. 61	−0. 117	0. 1565	−0. 75	−0. 036	−11. 5	0. 1563
−10. 05	−. 055	. 1409	−. 39	−. 035	−10. 0	. 1408
−8. 48	+. 018	. 1318	. 14	−. 056	−8. 5	. 1318
−6. 88	. 128	. 1057	1. 21	−. 017	−7. 0	. 1054
−5. 26	. 256	. 0901	2. 84	−. 001	−5. 5	. 0891
−3. 64	. 376	. 0788	4. 76	+. 016	−4. 0	. 0765
−2. 03	. 495	. 0782	6. 33	. 040	−2. 5	. 0742
−. 43	. 604	. 0795	7. 57	. 066	−1. 0	. 0735
+1. 19	. 730	. 0859	8. 48	. 092	+. 5	. 0771
2. 77	. 825	. 0929	8. 85	. 116	2. 0	. 0817
4. 40	. 948	. 1139	8. 34	. 134	3. 5	. 0991
6. 00	1. 052	. 1287	8. 20	. 103	5. 0	. 1104
7. 58	1. 139	. 1436	7. 94	. 155	6. 5	. 1223
9. 18	1. 242	. 1737	7. 15	. 118	8. 0	. 1482
10. 76	1. 332	. 1899	7. 00	. 129	9. 5	. 1606
12. 34	1. 412	- - - - -	- - - - -	- - - - -	11. 0	- - - - -
13. 84	1. 411	. 2565	5. 50	. 100	12. 5	. 2235
15. 35	1. 427	. 2858	5. 00	. 082	14. 0	. 2522
16. 87	1. 412	. 3321	4. 26	. 083	15. 5	. 2991
18. 34	1. 421	. 3523	4. 03	. 058	17. 0	. 3190
19. 84	1. 416	. 3949	3. 59	. 038	18. 5	. 3619
21. 53	1. 406	. 4185	3. 36	. 038	20. 0	. 3859
22. 82	1. 398	. 4485	3. 12	. 023	21. 5	. 4163
24. 30	1. 378	. 4879	2. 83	. 002	23. 0	. 4566
25. 80	1. 375	. 5143	2. 68	. 000	24. 5	. 4831

[1] Uncorrected for tunnel wall effect.

TABLE V

MODEL, BE-2E (R. A. F., 19 WINGS) AIRPLANE MODEL. AVERAGE TANK PRESSURE, 20.4 ATM. AVERAGE DYNAMIC PRESSURE, 637 kg/m². AVERAGE REYNOLDS NUMBER, 4,000,000

Degrees α	C_L	C_D	L/D	C_M	[1] Degrees α	[1] C_D'
−11. 58	−0. 080	0. 1416	−0. 57	−0. 002	−11. 5	0. 1415
−10. 04	−. 036	. 1268	−. 28	−. 004	−10. 0	. 1268
−8. 48	+. 036	. 1123	+. 32	+. 001	−8. 5	. 1123
−6. 89	. 114	. 0994	1. 15	. 009	−7. 0	. 0992
−5. 25	. 260	. 0896	2. 90	. 010	−5. 5	. 0885
−3. 62	. 403	. 0719	5. 59	. 038	−4. 0	. 0692
−2. 01	. 522	. 0698	7. 46	. 037	−2. 5	. 0653
−. 40	. 635	. 0740	8. 55	. 064	−1. 0	. 0673
+1. 21	. 752	. 0845	8. 93	. 075	+. 5	. 0752
2. 80	. 850	. 0961	8. 85	. 083	2. 0	. 0889
4. 41	. 963	. 1126	8. 55	. 099	3. 5	. 0973
6. 00	1. 058	. 1286	8. 20	. 105	5. 0	. 1102
7. 60	1. 168	. 1554	7. 53	. 116	6. 5	. 1329
9. 18	1. 247	. 1703	7. 30	. 112	8. 0	. 1447
10. 77	1. 343	. 1994	6. 75	. 121	9. 5	. 1696
12. 34	1. 413	. 2290	6. 18	. 099	11. 0	. 1960
13. 81	1. 382	. 2649	5. 21	. 068	12. 5	. 2334
15. 30	1. 374	. 3012	4. 57	. 053	14. 0	. 2700

[1] Uncorrected for tunnel wall effect.

TABLE VI

MODEL, BRISTOL FIGHTER (R. A. F., 15) AIRPLANE MODEL. AVERAGE TANK PRESSURE, 1 ATM. AVERAGE DYNAMIC PRESSURE, 27.8 kg/m². AVERAGE REYNOLDS NUMBER, 157,000

Degrees α	C_L	C_D	L/D	C_M	[1] Degrees α	[1] C_D'
−4. 58	−0. 114	0. 0616	−1. 85	−0. 075	−4. 5	0. 0614
−3. 00	+. 000	. 0513	+. 00	−. 012	−3. 0	. 0513
−1. 43	. 106	. 0502	2. 12	+. 001	−1. 5	. 0501
+. 13	. 199	. 0500	3. 99	. 004	0	. 0495
1. 70	. 296	. 0534	5. 53	. 008	+1. 5	. 0524
3. 26	. 387	. 0604	6. 38	. 022	3. 0	. 0587
4. 82	. 484	. 0684	7. 09	. 054	4. 5	. 0657
6. 37	. 558	. 0781	7. 14	. 013	6. 0	. 0745
7. 94	. 664	. 0226	7. 14	. 068	7. 5	. 0875
9. 50	. 749	. 1045	7. 14	. 070	9. 0	. 0980
11. 06	. 845	. 1206	7. 00	. 092	10. 5	. 1123
12. 62	. 926	. 1358	6. 81	. 102	12. 0	. 1258
14. 15	. 983	. 1575	6. 25	. 083	13. 5	. 1463
15. 66	. 986	. 2153	4. 59	. 080	15. 0	. 2040
17. 16	. 990	. 2578	3. 85	. 081	16. 5	. 2464
18. 64	. 968	. 2877	3. 37	. 065	18. 0	. 2768
20. 14	. 961	. 3353	2. 87	. 049	19. 5	. 3246
21. 62	. 939	. 3949	2. 38	+. 019	21. 0	. 3847
23. 12	. 930	. 4373	2. 13	−. 004	22. 5	. 4273
24. 60	. 901	. 4644	1. 94	−. 036	24. 0	. 4550
26. 08	. 877	. 4920	1. 78	−. 047	25. 5	. 4831

[1] Uncorrected for tunnel wall effect.

58820—28——3

TABLE VII

MODEL, BRISTOL FIGHTER (R. A. F., 15 WINGS) AIRPLANE MODEL. AVERAGE TANK PRESSURE, 2.58 ATM. AVERAGE DYNAMIC PRESSURE, 69.2 kg/m². AVERAGE REYNOLDS NUMBER, 390,000

Degrees α	C_L	C_D	L/D	C_M	[1] Degrees α	[1] C_D'
−4. 55	−0. 082	0. 0545	−1. 51	−0. 051	−4. 5	0. 0544
−2. 99	+. 013	. 0507	+. 26	−. 042	−3. 0	. 0507
−1. 42	. 114	. 0497	2. 29	−. 024	−1. 5	. 0495
+. 14	. 204	. 0513	3. 97	−. 009	0	. 0508
1. 70	. 294	. 0554	5. 32	−. 001	+1. 5	. 0544
3. 26	. 393	. 0615	6. 41	+. 024	3. 0	. 0598
4. 83	. 491	. 0685	7. 14	. 035	4. 5	. 0657
6. 39	. 585	. 0793	7. 41	. 043	6. 0	. 0753
7. 95	. 682	. 0909	7. 52	. 062	7. 5	. 0855
9. 51	. 770	. 1040	7. 41	. 079	9. 0	. 0971
11. 07	. 863	. 1178	7. 30	. 073	10. 5	. 1092
12. 63	. 951	. 1336	7. 14	. 095	12. 0	. 1231
14. 19	1. 032	. 1560	6. 63	. 104	13. 5	. 1436
15. 72	1. 067	. 1940	5. 50	. 079	15. 0	. 1808
17. 23	1. 092	. 2355	4. 63	. 085	16. 5	. 2217
18. 74	1. 110	. 2858	3. 89	. 081	18. 0	. 2715
20. 22	1. 086	. 3450	3. 14	. 065	19. 5	. 3313
21. 69	1. 041	. 3960	2. 63	. 044	21. 0	. 3834
23. 16	1. 000	. 4458	2. 24	. 015	22. 5	. 4342
24. 64	. 965	. 4788	2. 02	+. 009	4. 0	. 4684
26. 12	. 934	. 5078	1. 84	−. 031	25. 5	. 4977

[1] Uncorrected for tunnel wall effect.

TABLE VIII

MODEL, BRISTOL FIGHTER (R. A. F., 15 WINGS) AIRPLANE MODEL. AVERAGE TANK PRESSURE, 5.1 ATM. AVERAGE DYNAMIC PRESSURE, 146 kg/m². AVERAGE REYNOLDS NUMBER, 780,000

Degrees α	C_L	C_D	L/D	C_M	[1] Degrees α	[1] C_D'
−4. 55	−0. 068	0. 0502	−1. 36	−0. 051	−4. 5	0. 0501
−3. 00	+. 008	. 0484	+. 17	−. 026	−3. 0	. 0484
−1. 45	. 108	. 0478	2. 26	−. 024	−1. 5	. 0477
+. 13	. 199	. 0500	3. 99	−. 006	0	. 0495
1. 69	. 288	. 0537	5. 38	+. 012	+1. 5	. 0527
3. 26	. 392	. 0593	6. 63	. 032	3. 0	. 0575
4. 82	. 485	. 0666	7. 20	. 047	4. 5	. 0639
6. 38	. 574	. 0754	7. 64	. 059	6. 0	. 0716
7. 95	. 673	. 0882	7. 64	. 085	7. 5	. 0829
9. 51	. 762	. 1004	7. 58	. 089	9. 0	. 0937
11. 07	. 851	. 1143	7. 46	. 108	10. 5	. 1059
12. 62	. 932	. 1323	7. 04	. 104	12. 0	. 1223
14. 18	1. 024	. 1549	6. 63	. 119	13. 5	. 1427
15. 70	1. 053	. 2014	5. 24	. 111	15. 0	. 1885
17. 21	1. 072	. 2270	4. 46	. 087	16. 5	. 1925
18. 72	1. 065	. 2829	3. 76	. 091	18. 0	. 2697
20. 20	1. 059	. 3385	3. 13	. 078	19. 5	. 3255
21. 69	1. 037	. 3979	2. 61	. 039	21. 0	. 3854
23. 18	1. 017	. 4365	2. 33	. 041	22. 5	. 4245
24. 66	. 986	. 4745	2. 08	+. 004	24. 0	. 4632
26. 13	. 948	. 5038	1. 88	−. 002	25. 5	. 4934

[1] Uncorrected for tunnel wall effect.

TABLE IX

MODEL, BRISTOL FIGHTER (R. A. F., 15 WINGS) AIRPLANE MODEL. AVERAGE TANK PRESSURE, 10.5 ATM. AVERAGE DYNAMIC PRESSURE, 307 kg/m². AVERAGE REYNOLDS NUMBER, 1,580,000

Degrees α	C_L	C_D	L/D	C_M	[1] Degrees α	[1] C_D'
−4.56	−0.084	0.0434	−1.93	−0.048	−4.5	0.0433
−3.00	+.003	.0429	+.07	−.037	−3.0	.0429
−1.44	.096	.0428	2.24	−.043	−1.5	.0427
+.13	.193	.0441	4.37	−.006	0	.0437
1.68	.268	.0461	5.82	−.036	+1.5	.0453
3.24	.366	.0518	7.10	+.010	3.0	.0502
4.81	.463	.0627	7.41	.086	4.5	.0602
6.37	.558	.0679	8.20	.094	6.0	.0643
7.92	.639	.0744	8.63	.087	7.5	.0697
9.48	.729	.1026	7.10	.098	9.0	.0964
11.06	.848	.1080	7.88	.082	10.5	.0996
12.60	.905	.1202	7.52	.029	12.0	.1107
14.18	1.017	.1429	7.10	.084	13.5	.1309
15.68	1.021	.2006	5.11	.073	15.0	.1885
17.19	1.039	.2363	4.41	.057	16.5	.2237
18.68	1.022	.2733	3.74	.050	18.0	.2611
20.16	.999	.3257	3.07	.025	19.5	.3141
21.66	.997	.3639	2.72	+.016	21.0	.3524
23.16	.987	.4253	2.32	−.019	22.5	.4140
24.65	.978	.4549	2.15	−.010	24.0	.4438
26.14	.960	.5058	1.90	−.041	25.5	.4951

[1] Uncorrected for tunnel wall effect.

TABLE X

MODEL, BRISTOL FIGHTER (R. A. F., 15 WINGS) AIRPLANE MODEL. AVERAGE TANK PRESSURE, 20.6 ATM. AVERAGE DYNAMIC PRESSURE, 618 kg/m². AVERAGE REYNOLDS NUMBER, 3,120,000

Degrees α	C_L	C_D	L/D	C_M	[1] Degrees α	[1] C_D'
−4.56	−0.090	0.0436	−2.07	−0.053	−4.5	0.0435
−3.00	+.000	.0412	+.00	−.032	−3.0	.0412
−1.43	.099	.0414	2.40	−.025	−1.5	.0413
+.12	.180	.0427	4.22	−.021	0	.0423
1.68	.277	.0461	5.99	+.025	+1.5	.0452
3.25	.377	.0526	7.20	.016	3.0	.0510
4.81	.466	.0594	7.88	.030	4.5	.0569
6.37	.555	.0683	8.14	.053	6.0	.0647
7.93	.647	.0778	8.34	.062	7.5	.0730
9.49	.737	.0910	8.14	.082	9.0	.0847
11.06	.836	.1075	7.75	.052	10.5	.0994
12.61	.920	.1218	7.58	.102	12.0	.1120
14.17	1.004	.1391	7.20	.101	13.5	.1274
15.69	1.032	.1606	6.41	.100	15.0	.1482
17.17	1.013	.2305	4.39	.079	16.5	.2186
18.66	.997	.2737	3.64	.059	18.0	.2622
20.14	.964	.3145	3.07	.040	19.5	.3037
21.62	.931	.3581	2.60	.008	21.0	.3481
23.13	.943	.3972	2.37	.012	22.5	.3869

[1] Uncorrected for tunnel wall effect.

TABLE XI

MODEL, BRISTOL FIGHTER (R. A. F., 30 WINGS) AIRPLANE MODEL. AVERAGE TANK PRESSURE, 1 ATM. AVERAGE DYNAMIC PRESSURE, 27.2 kg/m². AVERAGE REYNOLDS NUMBER, 152,000

Degrees α	C_L	C_D	L/D	C_M	[1] Degrees α	[1] C_D'
−1. 52	−0. 067	0. 0603	−1. 11	+0. 015	−1. 48	0. 0602
+. 01	+. 019	. 0569	+. 33	−. 003	0	. 0569
1. 56	. 120	. 0570	2. 10	+. 020	+1. 48	. 0568
3. 10	. 211	. 0601	3. 51	. 017	2. 96	. 0596
4. 64	. 301	. 0652	4. 63	. 042	4. 44	. 0642
6. 17	. 400	. 0726	5. 50	. 072	5. 91	. 0708
7. 71	. 492	. 0827	5. 95	. 078	7. 39	. 0799
9. 25	. 584	. 0938	6. 21	. 116	8. 86	. 0899
10. 77	. 662	. 1071	6. 18	. 134	10. 33	. 1021
12. 29	. 726	. 1228	5. 92	. 125	11. 81	. 1167
13. 78	. 761	. 1524	5. 00	. 173	13. 28	. 1457
15. 23	. 745	. 2084	3. 57	. 155	14. 74	. 2020
16. 69	. 733	. 2537	2. 89	. 155	16. 21	. 2475
18. 13	. 712	. 3005	2. 37	. 137	17. 66	. 2947
19. 58	. 696	. 3341	2. 08	. 117	19. 12	. 3285
21. 01	. 687	. 3670	1. 87	. 110	20. 56	. 3616

[1] Uncorrected for tunnel wall effect.

TABLE XII

MODEL, BRISTOL FIGHTER (R. A. F., 30 WINGS) AIRPLANE MODEL. AVERAGE TANK PRESSURE, 2.72 ATM. AVERAGE DYNAMIC PRESSURE, 72.8 kg/m². AVERAGE REYNOLDS NUMBER, 404,000

Degrees α	C_L	C_D	L/D	C_M	[1] Degrees α	[1] C_D'
−1. 52	−0. 066	0. 0536	−1. 23	−0. 013	−1. 48	0. 0535
+. 02	+. 029	. 0517	+. 56	−. 005	0	. 0517
1. 57	. 130	. 0517	2. 52	+. 017	+1. 48	. 0515
3. 11	. 221	. 0557	3. 97	. 029	2. 96	. 0551
4. 64	. 304	. 0606	5. 03	. 037	4. 44	. 0595
6. 17	. 397	. 0690	5. 75	. 055	5. 91	. 0672
7. 71	. 487	. 0769	6. 33	. 074	7. 39	. 0742
9. 24	. 579	. 0872	6. 62	. 091	8. 86	. 0833
10. 77	. 665	. 1003	6. 62	. 113	10. 33	. 0952
12. 31	. 751	. 1139	6. 58	. 127	11. 81	. 1074
13. 82	. 814	. 1280	6. 37	. 119	13. 28	. 1204
15. 27	. 809	. 1922	4. 21	. 129	14. 74	. 1847
16. 74	. 798	. 2368	3. 37	. 116	16. 21	. 2295
18. 16	. 755	. 2868	2. 63	. 085	17. 66	. 2802
19. 60	. 730	. 3274	2. 23	. 077	19. 12	. 3213
21. 04	. 721	. 3621	1. 99	. 065	20. 56	. 3561

[1] Uncorrected for tunnel wall effect.

TABLE XIII

MODEL, BRISTOL FIGHTER (R. A. F., 30 WINGS) AIRPLANE MODEL. AVERAGE TANK PRESSURE, 5.27 ATM. AVERAGE DYNAMIC PRESSURE, 141 kg/m². AVERAGE REYNOLDS NUMBER, 760,000

Degrees α	C_L	C_D	L/D	C_M	[1] Degrees α	[1] C_D'
−1. 52	−0. 063	0. 0522	−1. 21	−0. 022	−1. 48	0. 0522
+. 02	+. 033	. 0508	. 65	−. 015	0	. 0508
1. 57	. 131	. 0524	2. 50	+. 003	+1. 48	. 0522
3. 10	. 218	. 0557	3. 91	. 013	2. 96	. 0552
4. 64	. 306	. 0605	5. 05	. 033	4. 44	. 0594
6. 17	. 396	. 0672	5. 89	. 048	5. 91	. 0654
7. 71	. 485	. 0763	6. 37	. 058	7. 39	. 0736
9. 24	. 576	. 0870	6. 63	. 082	8. 86	. 0832
10. 77	. 666	. 0986	6. 76	. 093	10. 33	. 0935
12. 30	. 750	. 1113	6. 76	. 110	11. 81	. 1048
13. 83	. 831	. 1232	6. 76	. 114	13. 28	. 1156
15. 34	. 913	. 1392	6. 54	. 111	14. 74	. 1296
16. 81	. 916	. 1877	4. 88	. 096	16. 21	. 1780
18. 24	. 883	. 2338	3. 78	. 102	17. 66	. 2248
19. 69	. 870	. 2946	2. 95	. 094	19. 12	. 2859
21. 08	. 783	. 3613	2. 17	. 039	20. 56	. 3542

[1] Uncorrected for tunnel wall effect.

TABLE XIV

MODEL, BRISTOL FIGHTER (R. A. F., 30 WINGS) AIRPLANE MODEL. AVERAGE TANK PRESSURE, 10.33 ATM. AVERAGE DYNAMIC PRESSURE, 290 kg/m². AVERAGE REYNOLDS NUMBER, 1,500,000

Degrees α	C_L	C_D	L/D	C_M	[1] Degrees α	[1] C_D'
−1. 52	−0. 070	0. 0471	−1. 49	−0. 040	−1. 48	0. 0470
+. 00	−. 005	. 0461	−. 11	−. 094	0	. 0461
1. 55	+. 103	. 0468	+2. 20	+. 014	+1. 48	. 0467
3. 09	. 193	. 0504	3. 83	. 029	2. 96	. 0500
4. 62	. 278	. 0554	5. 03	. 052	4. 44	. 0545
6. 16	. 375	. 0620	6. 06	. 076	5. 91	. 0604
7. 68	. 441	. 0695	6. 33	. 046	7. 39	. 0673
9. 23	. 566	. 0787	7. 20	. 104	8. 86	. 0750
10. 76	. 651	. 0991	6. 58	. 114	10. 33	. 0942
12. 30	. 744	. 1034	7. 20	. 065	11. 81	. 0970
13. 84	. 851	. 1198	7. 10	. 120	13. 28	. 1115
15. 36	. 938	. 1344	7. 00	. 119	14. 74	. 1242
16. 87	1. 002	. 1528	6. 58	. 073	16. 21	. 1412
18. 33	1. 022	. 1814	5. 65	. 111	17. 66	. 1694
19. 83	1. 067	. 2225	4. 81	. 073	19. 12	. 2094
21. 24	1. 031	. 2563	4. 03	. 099	20. 56	. 2441
22. 66	. 993	. 3382	2. 94	. 038	22. 00	. 3268
24. 05	+. 941	. 3693	2. 55	. 005	23. 43	. 3591

[1] Uncorrected for tunnel wall effect.

TABLE XV

MODEL, BRISTOL FIGHTER (R. A. F., 30 WINGS) AIRPLANE MODEL. AVERAGE TANK PRESSURE, 21.0 ATM. AVERAGE DYNAMIC PRESSURE, 620 kg/m². AVERAGE REYNOLDS NUMBER, 3,050,000

Degrees α	C_L	C_D	L/D	C_M	[1] Degrees α	[1] C_D'
−1. 52	−0. 059	0. 0449	−1. 31	−0. 020	−1. 48	0. 0449
+. 02	+. 026	. 0439	+. 59	−. 012	0	. 0439
1. 57	. 130	. 0443	2. 93	+. 017	+1. 48	. 0441
3. 10	. 213	. 0472	4. 51	. 019	2. 96	. 0467
4. 64	. 297	. 0509	5. 85	. 033	4. 44	. 0499
6. 17	. 398	. 0592	6. 72	. 017	5. 91	. 0574
7. 70	. 476	. 0669	7. 10	. 056	7. 39	. 0643
9. 23	. 562	. 0771	7. 30	. 052	8. 86	. 0735
10. 76	. 650	. 0849	7. 64	. 069	10. 33	. 0800
12. 30	. 747	. 1051	7. 10	. 097	11. 81	. 0987
13. 83	. 832	. 1145	7. 25	. 097	13. 28	. 1065
15. 35	. 927	. 1316	7. 05	. 123	14. 74	. 1217
16. 87	1. 006	. 1513	6. 66	. 137	16. 21	. 1397
18. 32	. 999	. 1964	5. 08	. 107	17. 66	. 1849
19. 76	. 976	. 2358	4. 13	. 084	19. 12	. 2249
21. 14	. 876	. 3109	2. 82	. 032	20. 56	. 3021

[1] Uncorrected for tunnel wall effect.

TABLE XVI

DATA ON MODELS

Model	BE-2E	Bristol Fighter	Bristol Fighter
Wing section	R. A. F. 19	R. A. F. 15	R. A. F. 30.
Scale ratio	1:12	1:15	1:15.
Span upper wing	40 in. (101.6 cm.)	31.50 in. (80 cm.)	30.54 in. (77.57 cm.).
Span lower wing	30 in. (76.20 cm.)	31.50 in. (80 cm.)	30.54 in. (77.57 cm.).
Gap (average)	6.23 in. (15.82 cm.)	4.35 in. (11.05 cm.)	4.35 in. (11.05 cm.).
Chord upper wing	5.50 in. (13.97 cm.)	4.40 in. (11.18 cm.)	4.38 in. (11.13 cm.).
Chord lower wing	5.50 in. (13.97 cm.)	4.40 in. (11.18 cm.)	4.40 in. (11.18 cm.).
Area upper wing	1.507 sq. ft. (0.1400 sq. m.)	0.907 sq. ft. (0.0843 sq. m.)	0.901 sq. ft. (0.0837 sq. m.).
Area lower wing	1.019 sq. ft. (0.0947 sq. m.)	0.907 sq. ft. (0.0843 sq. m.)	0.907 sq. ft. (0.0843 sq. m.).
Area total	2.526 sq. ft. (0.2347 sq. m.)	1.814 sq. ft. (0.1685 sq. m.)	1.808 sq. ft. (0.1680 sq. m.).

PITCHING MOMENT AXIS

BE–2E (*R. A. F., 19*).—The axis, relative to the leading edge of the upper wing chord at root, is 3.46 inches behind and 4.72 inches below, parallel and perpendicular to the chord line.

Bristol Fighter (*R. A. F., 15*).—The axis, relative to the leading edge of the lower wing chord at root, is 1.125 inches behind and 2.06 inches above, parallel and perpendicular to the chord line.

Bristol Fighter (*R. A. F., 30*).—The axis, relative to the leading edge of the lower wing chord at root, is 1.125 inches behind and 2.03 inches above, parallel and perpendicular to the chord line.

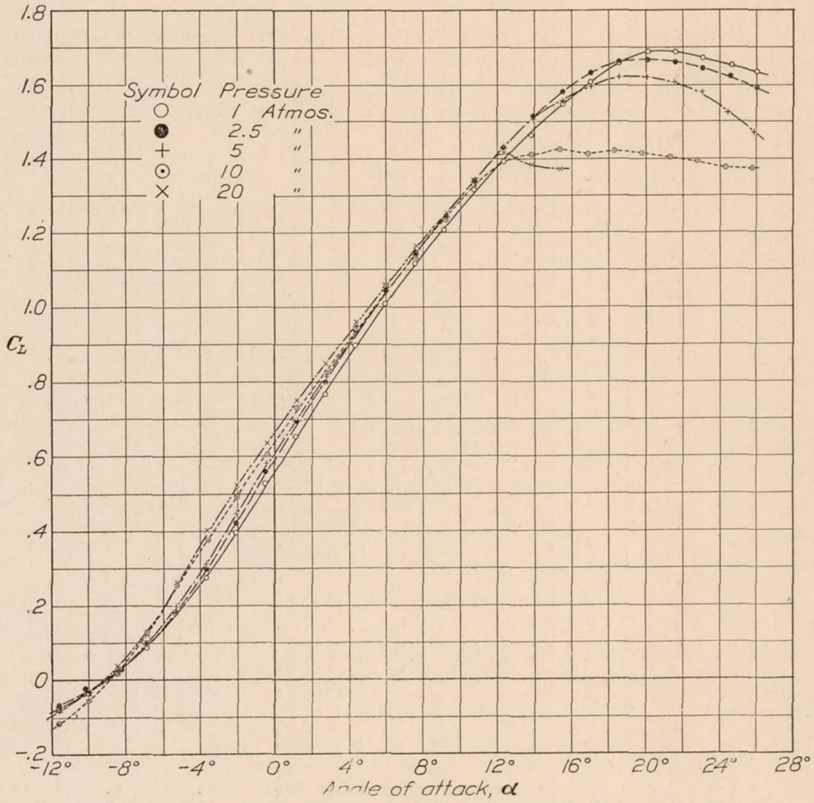

FIG. 6.—Lift coefficient vs. angle of attack. BE-2E airplane model with R. A. F. 19 wings

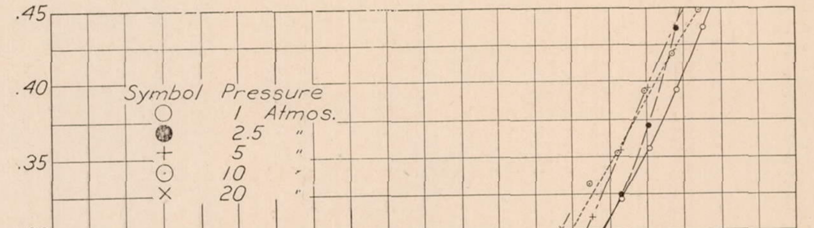

FIG. 7.—Drag coefficient vs. angle of attack. BE-2E airplane model with R. A. F. 19 wings

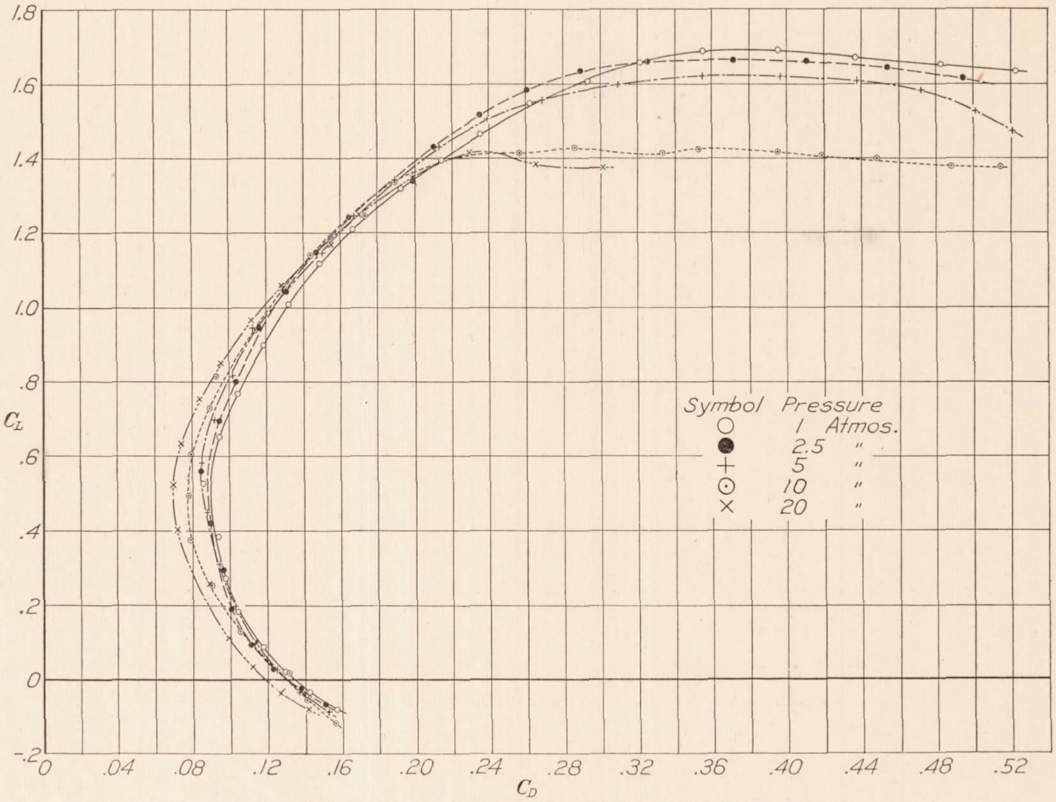

FIG. 8.—Lift coefficient vs. drag coefficient. BE-2E airplane model with R. A. F. 19 wings

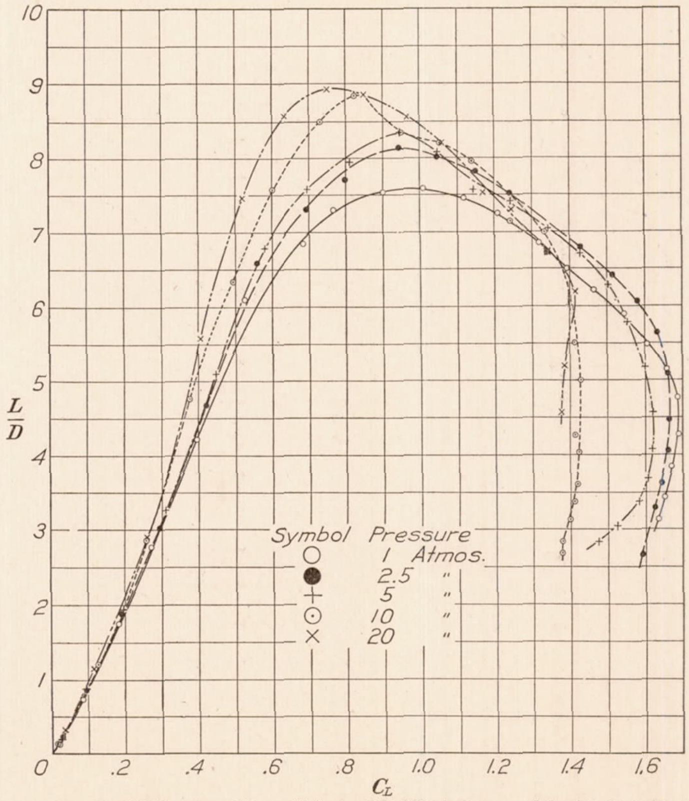

FIG. 9.—Lift/drag vs. lift coefficient. BE-2E airplane model with R. A. F. 19 wings

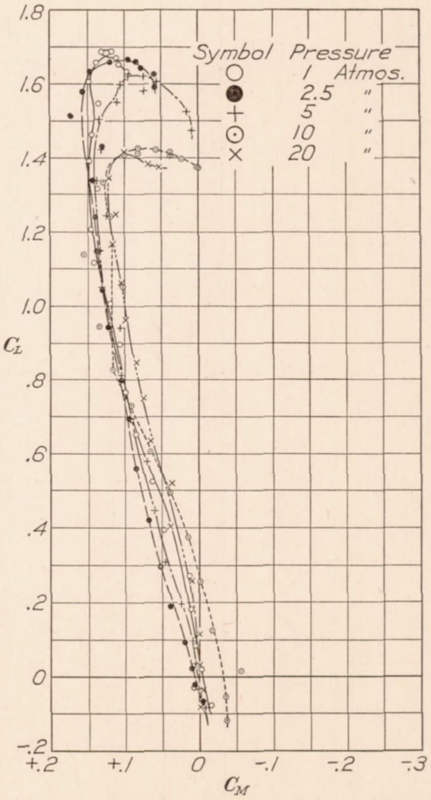

FIG. 10.—Lift coefficient vs. moment coefficient. BE-2E airplane model with R. A. F. 19 wings

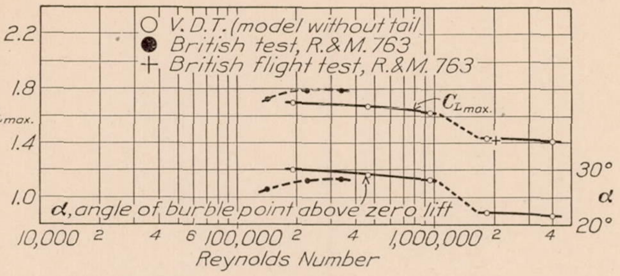

FIG. 11.—Scale effect on $C_{L_{max.}}$ BE-2E airplane model with R. A. F. 19 wings

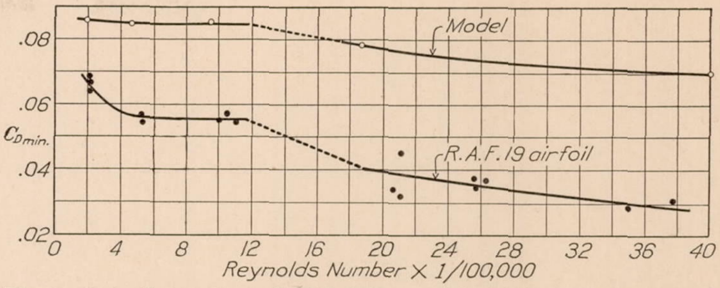

FIG. 13.—Scale effect on $C_{D_{min.}}$ BE-2E airplane model with R. A. F. 19 wings and without tail group

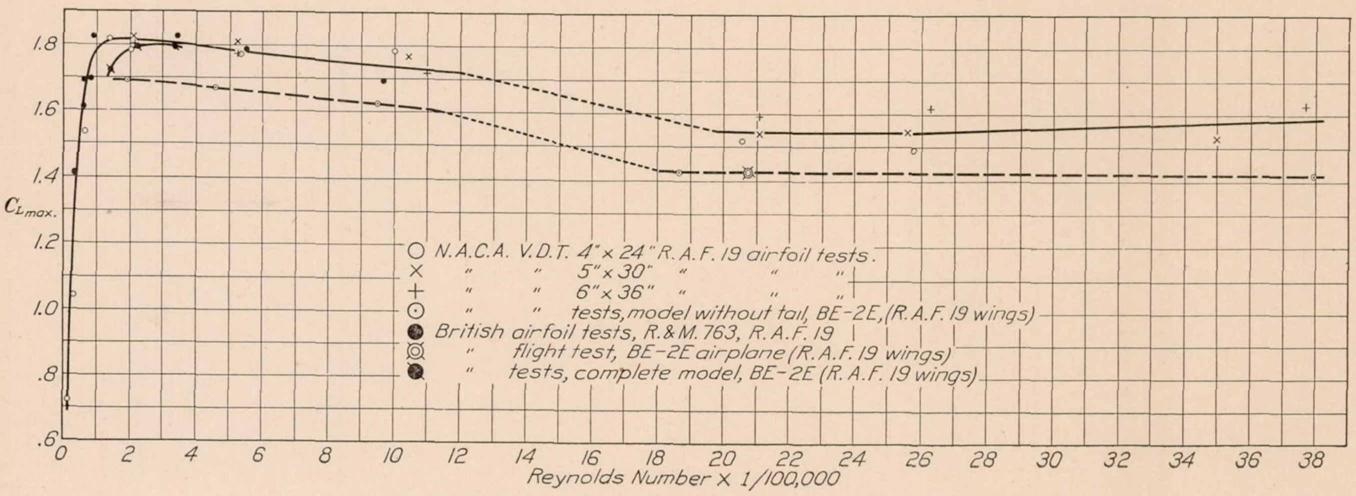

FIG. 12.—Scale effect on $C_{L_{max.}}$ BE-2E airplane model with R. A. F. 19 wings

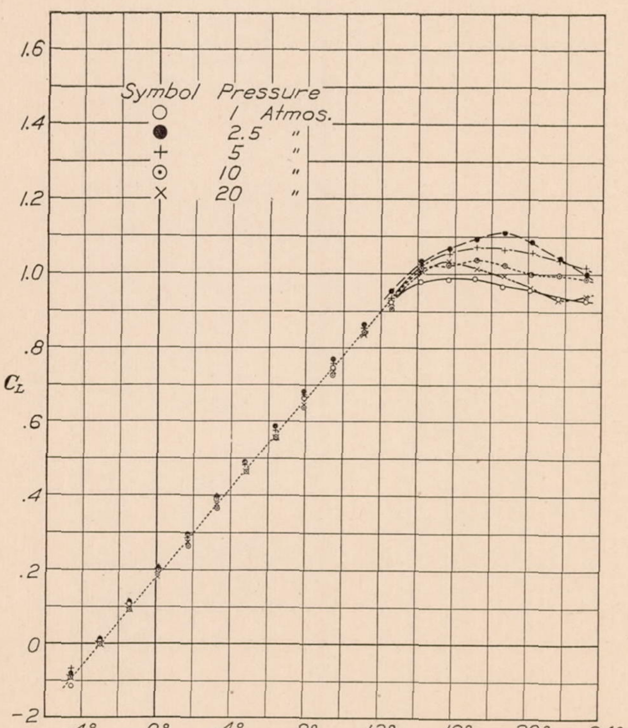

FIG. 14.—Lift coefficient vs. angle of attack. Bristol Fighter airplane model with R.A. F. 15 wings

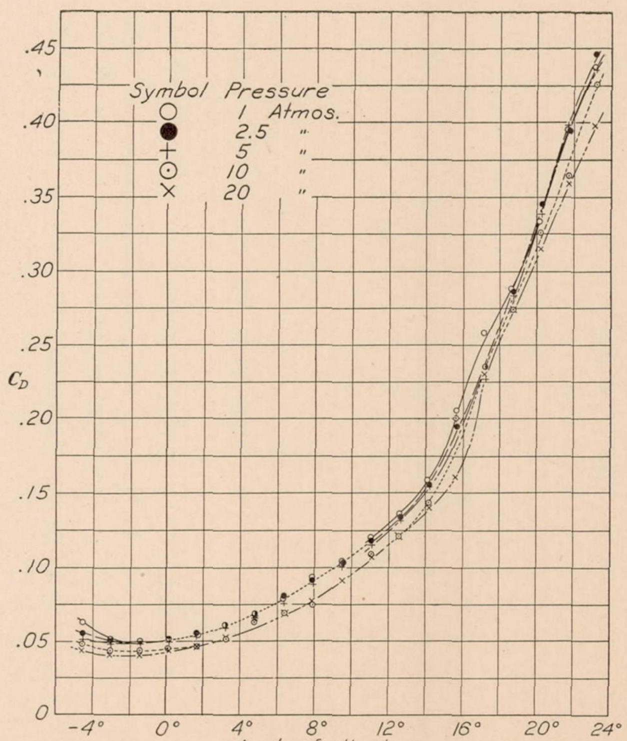

FIG. 15.—Drag coefficient vs. angle of attack. Bristol Fighter airplane model with R. A. F. 15 wings

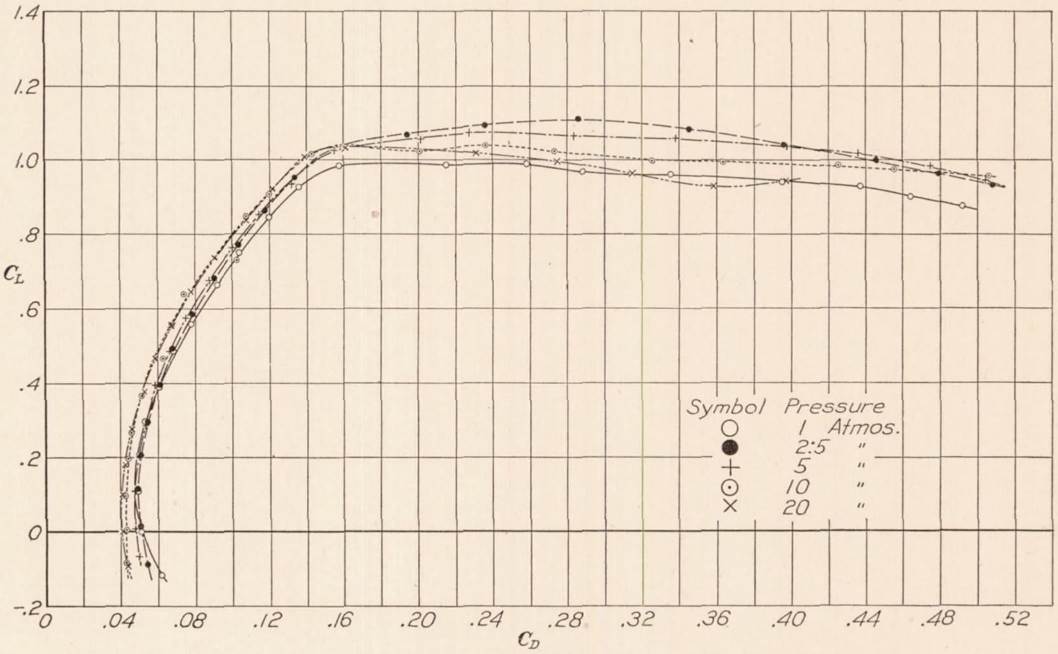

FIG. 16.—Lift coefficient vs. drag coefficient. Bristol Fighter airplane model with R. A. F. 15 wings

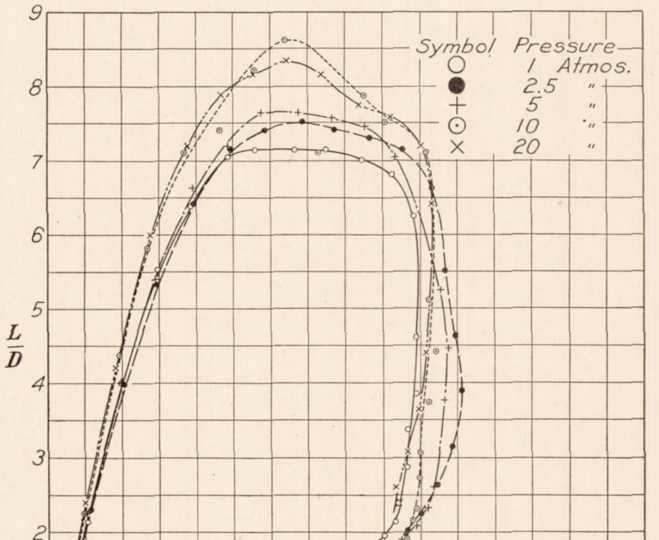

FIG. 17.—Lift/drag vs. lift coefficient. Bristol Fighter airplane model with R. A. F. 15 wings

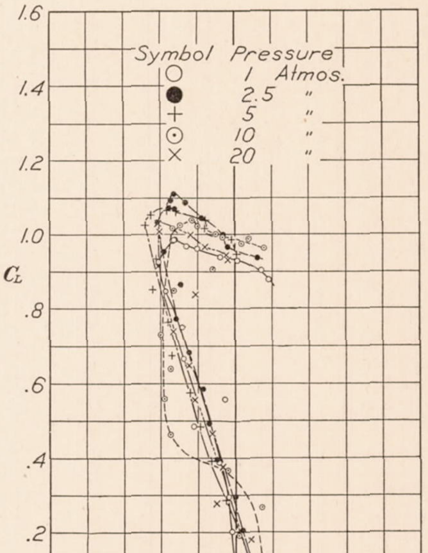

FIG. 18.—Lift coefficient vs. moment coefficient. Bristol Fighter airplane model with R. A. F. 15 wings

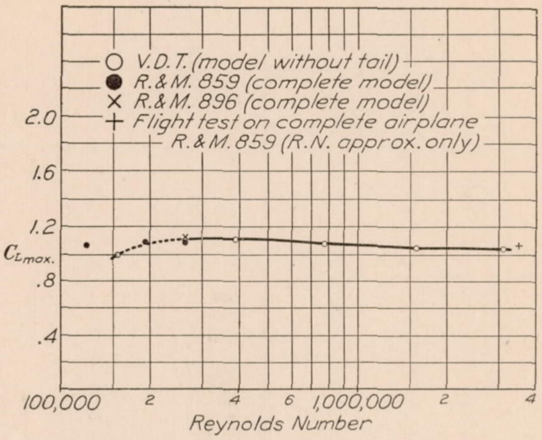

FIG. 19.—Scale effect on $C_{L_{max.}}$ Bristol Fighter airplane model with R. A. F. 15 wings

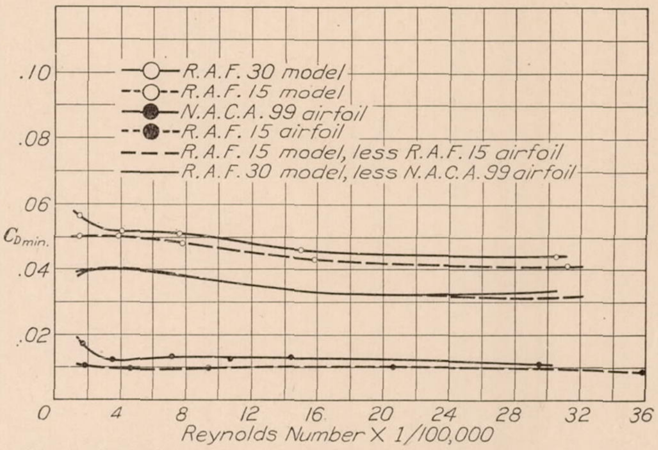

FIG. 20.—Scale effect on $C_{D_{min.}}$ Bristol Fighter airplane model without tail group

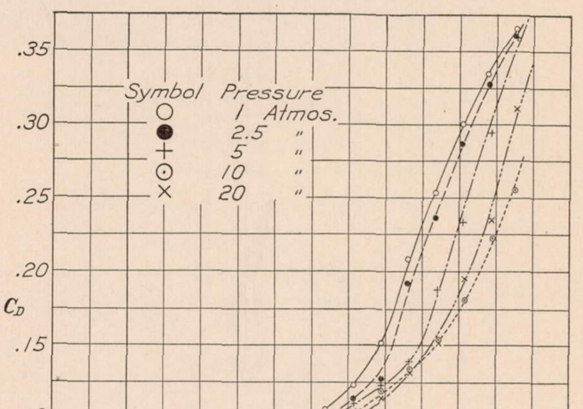

FIG. 21.—Lift coefficient vs. angle of attack. Bristol Fighter airplane model with R. A. F. 30 wings

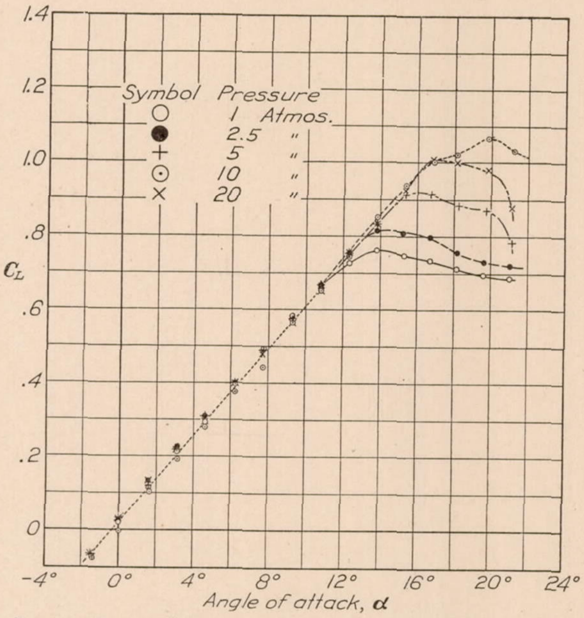

FIG. 22.—Drag coefficient vs. angle of attack. Bristol fighter airplane model with R. A. F. 30 wings

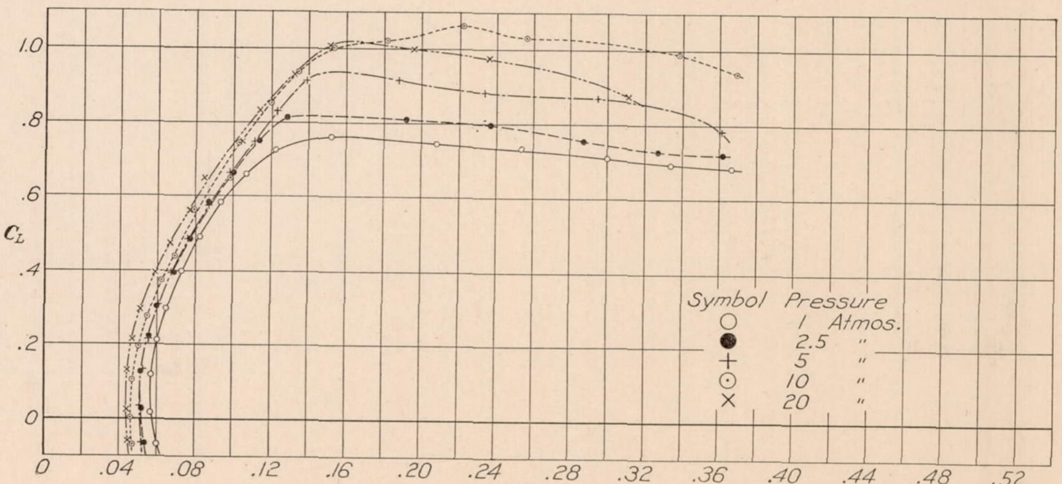

FIG. 23.—Lift coefficient vs. drag coefficient. Bristol Fighter airplane model with R. A. F. 30 wings

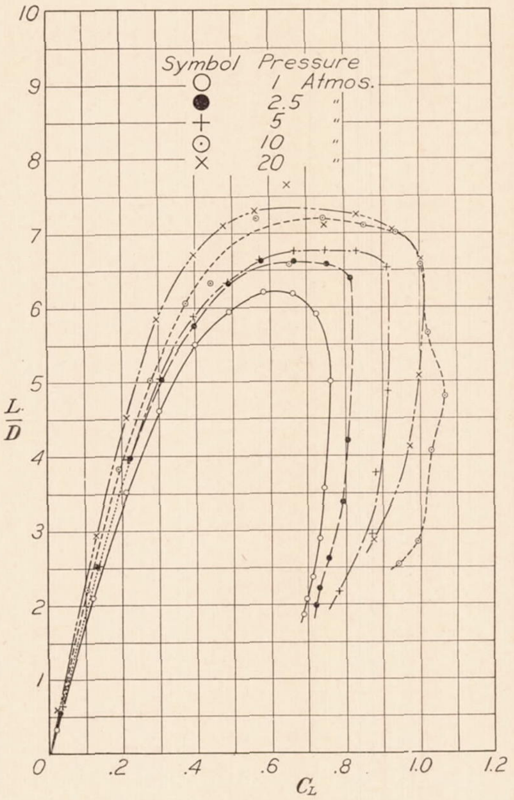

FIG. 24.—Lift/drag vs. lift coefficient. Bristol Fighter airplane model with R. A. F. 30 wings

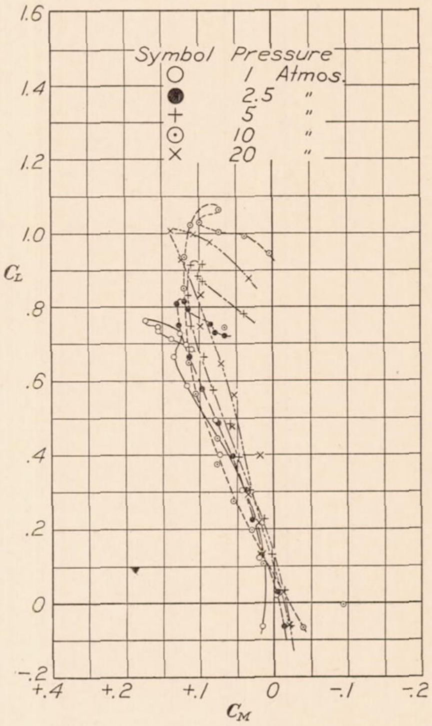

FIG. 25.—Lift coefficient vs. moment coefficient. Bristol Fighter airplane model with R. A. F. 30 wings

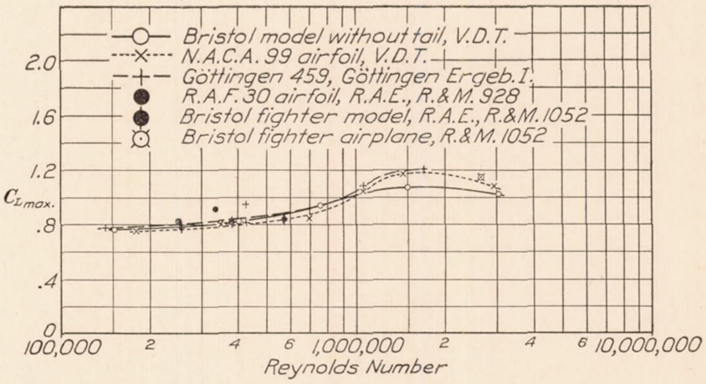

FIG. 26.—Scale effect on $C_{L_{max.}}$ Bristol Fighter airplane model with R. A. F. 30 wings

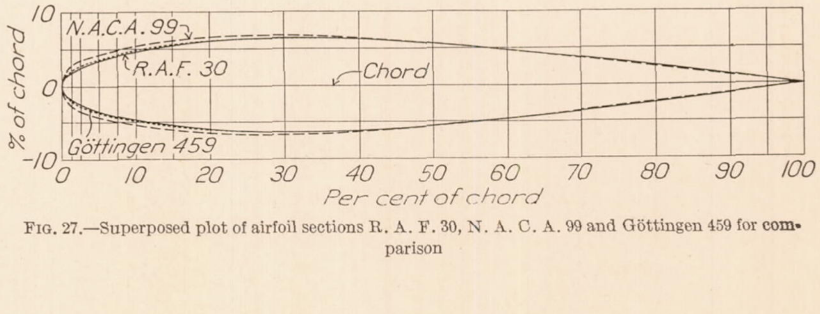

FIG. 27.—Superposed plot of airfoil sections R. A. F. 30, N. A. C. A. 99 and Göttingen 459 for comparison

APPENDIX

REPORT OF

AERODYNAMICS SUBCOMMITTEE

BRITISH AERONAUTICAL RESEARCH COMMITTEE

TESTS OF THREE AIRPLANE MODELS

By H. C. H. Townend, B. Sc.

Tests have been made of models of BE2e with R. A. F. 19 wings, Bristol Fighter with R. A. F. 15 wings, and Bristol Fighter with R. A. F. 30 wings, for comparison with those obtained with the same models in the variable density tunnel of the National Advisory Committee for Aeronautics, America. Owing to lack of time it has not been possible to produce a complete report, and in consequence the absolute lift and drag coefficients only are given here, the moment coefficients being omitted for the present.

The wind velocity was adjusted in each case to give the same value of Vl/ν as in the corresponding test at atmospheric pressure in the N. A. C. A. tunnel. The particulars of the models as given in Table XVI of this report have been used in obtaining lift and drag coefficients.

The models were tested exactly as they were received, with the exception of the BE2e, which was found to be damaged on arrival. In addition to other minor defects, the lower wing was found to be slightly loose, yawed about 2°, displaced bodily about $\frac{3}{16}$ inch to starboard and bent at the root in such a way that its angle of attack was about $\frac{1}{3}$° in error. With the exception of the lateral displacement, the above defects were rectified before test.

Results.—The results have been corrected for effect of the tunnel walls. There is some doubt about the exact direction of the wind in the tunnel in which the models were tested which introduces some uncertainty in the value of minimum drag and it has not been possible to test for this yet.

The absolute lift and drag coefficients are plotted in Figures 28, 29, and 30. The agreement with the results in the variable density tunnel is very close for all the models. In the case of the BE2e with R. A F. 19 wings the sharp fall in C_L above the maximum, which is characteristic of this wing section, does not occur in the N. A. C. A. tests, the results of which for this model are particularly smooth near the stall.

June, 1927.

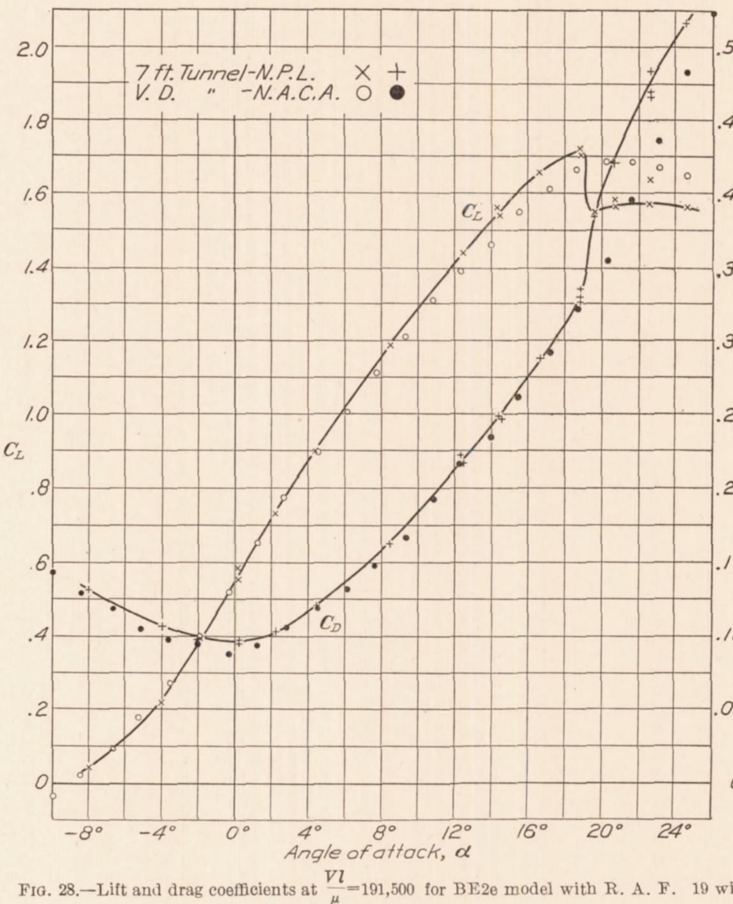

Fig. 28.—Lift and drag coefficients at $\frac{Vl}{\mu}=191{,}500$ for BE2e model with R. A. F. 19 wings (without tail unit)

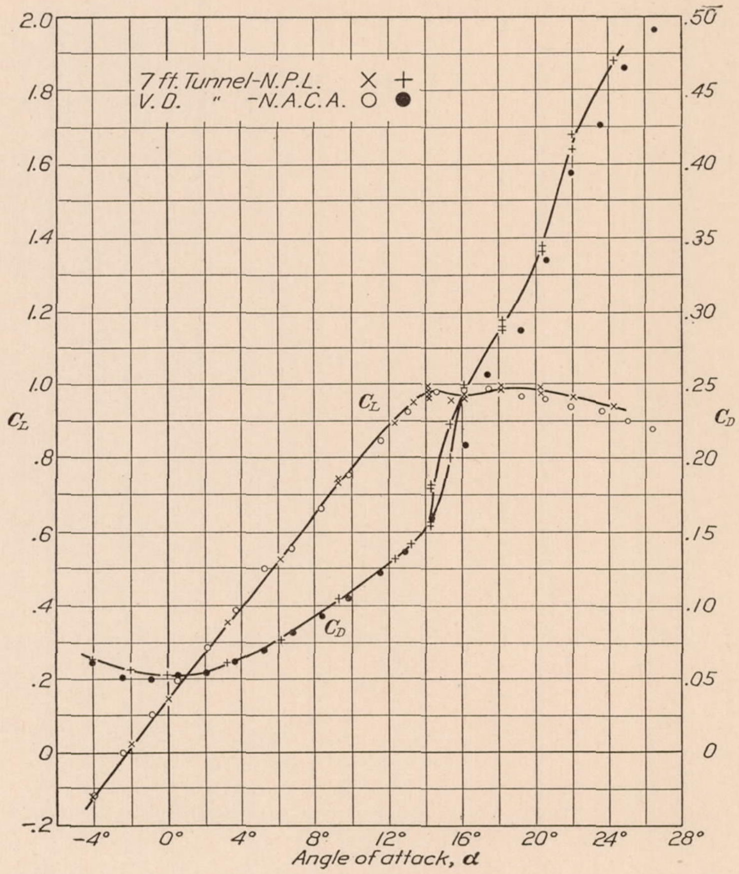

FIG. 29.—Lift and drag coefficients at $\frac{Vl}{\mu}$=157,000 for BE2e model with R. A. F. 15 wings (without tail unit)

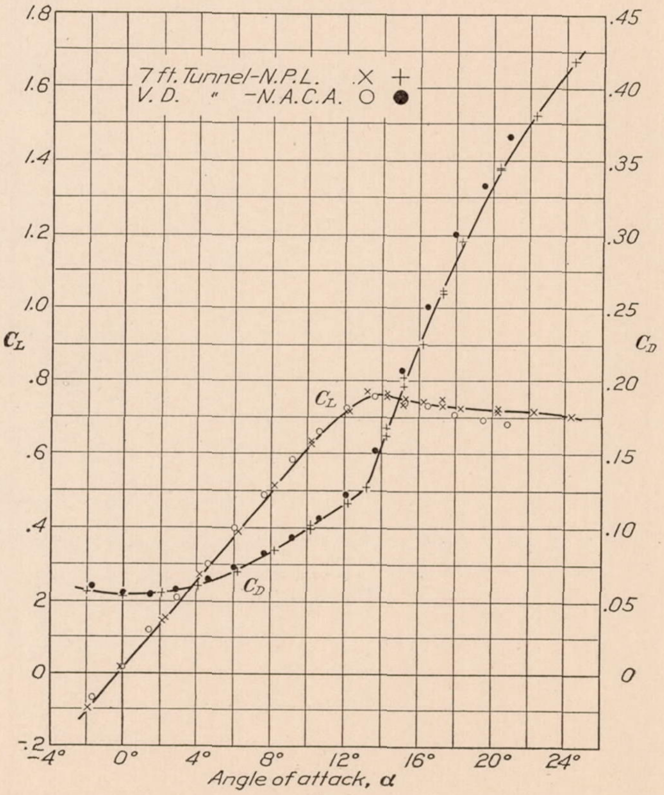

FIG. 30.—Lift and drag coefficients at $\frac{Vl}{\mu}$=152,000 for BE2e model with R. A. F. 30 wings (without tail unit)

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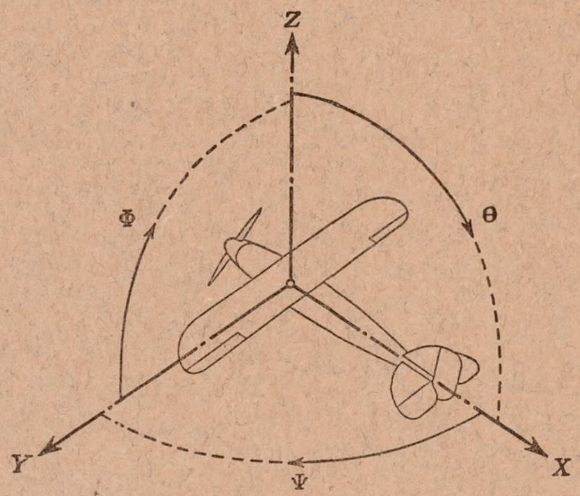

Positive directions of axes and angles (forces and moments) are shown by arrows

Axis		Force (parallel to axis) symbol	Moment about axis			Angle		Velocities	
Designation	Symbol		Designation	Symbol	Positive direction	Designation	Symbol	Linear (component along axis)	Angular
Longitudinal	X	X	rolling	L	$Y \longrightarrow Z$	roll	Φ	u	p
Lateral	Y	Y	pitching	M	$Z \longrightarrow X$	pitch	Θ	v	q
Normal	Z	Z	yawing	N	$X \longrightarrow Y$	yaw	Ψ	w	r

Absolute coefficients of moment

$$C_L=\frac{L}{qbS}\quad C_M=\frac{M}{qcS}\quad C_N=\frac{N}{qfS}$$

Angle of set of control surface (relative to neutral position), δ. (Indicate surface by proper subscript.)

4. PROPELLER SYMBOLS

D, Diameter.
p_e, Effective pitch
p_g, Mean geometric pitch.
p_s, Standard pitch.
p_v, Zero thrust.
p_a, Zero torque.
p/D, Pitch ratio.
V', Inflow velocity.
V_s, Slip stream velocity.

T, Thrust.
Q, Torque.
P, Power.
(If "coefficients" are introduced all units used must be consistent.)
η, Efficiency $= T\,V/P$.
n, Revolutions per sec., r. p. s.
N, Revolutions per minute., R. P. M.
Φ, Effective helix angle $=\tan^{-1}\left(\frac{V}{2\pi rn}\right)$

5. NUMERICAL RELATIONS

1 HP = 76.04 kg/m/sec. = 550 lb./ft./sec.
1 kg/m/sec. = 0.01315 HP.
1 mi./hr. = 0.44704 m/sec.
1 m/sec. = 2.23693 mi./hr.

1 lb. = 0.4535924277 kg.
1 kg = 2.2046224 lb.
1 mi. = 1609.35 m = 5280 ft.
1 m = 3.2808333 ft.